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(54) Fluorovinylethers and polymers obtainable therefrom

(57) Fluorovinylethers having the formula $CFX=CXOCF_2OR$, wherein R is a C_2-C_6 linear, branched or C_5-C_6 cyclic (per)fluoroalkyl group, or a C_2-C_6 linear, branched (per)fluoro oxyalkyl group containing from one to three oxygen atoms; when R is fluoro-

alkyl or fluoroalkoxyalkyl group as above defined, it can contain from 1 to 2 atoms, equal or different, selected from the following: H, Cl, Br, I; X = F, H; and homopolymers or polymers obtainable polymerizing said fluorovinylethers with at least another polymerizable monomer.

EP 1 148 041 A2

Description

[0001] The present invention relates to fluorovinylethers, the process for preparing them and the polymers obtainable therefrom.

[0002] It is well known that perfluoroalkylvinylethers are used as monomers for the olefin copolymerization, specifically tetrafluoroethylene, vinylidene fluoride, chlorotrifluoroethylene (CTFE), hexafluoropropene. The introduction of small amounts of perfluoroalkylvinylethers in elastomeric polymers implies a higher polymer processability and better hot mechanical properties. The introduction of high amounts of perfluoroalkylvinylethers in crosslinkable fluoropolymers implies elastomeric properties at low temperature of fluorinated rubbers.

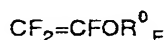
[0003] The need was felt, in the fluorinated polymeric material field, to produce both elastomers having good properties at high temperatures, and elastomers having improved properties at low temperatures by using only one fluorovinylether.

[0004] Such properties at low temperatures can generally be expressed by the glass transition temperature T_g.

[0005] Furthermore the need was felt to have available amorphous or crystalline (co)polymers having a low content of COF end groups. A lower content of COF end groups leads to obtain polymers having a higher thermal stability. A lower T_g allows to have polymers which can be used at lower temperatures and therefore to have available elastomers with a wider use range. To obtain the combination of the above mentioned properties, fluorovinylethers must have a high unitary capability to modify the backbone properties, as well as high reactivity to be used as comonomers both in elastomeric and in elastomeric fluoropolymers. It was desirable to have available vinyl ethers obtainable by simple processes having a limited number of steps. Preferably it would be desirable to have available a continuous process for preparing said vinyl ethers.

[0006] To solve the above technical problem, fluorovinylethers having different structural properties, have been proposed in the prior art. However from the prior art, hereinafter described, various unsolved problems exist in the perfluorovinylether synthesis and in the preparation of the corresponding polymers having the combination of the above mentioned properties.

[0007] USP 3,132,123 describes the preparation of perfluoroalkylvinylethers, of the corresponding homopolymers and copolymers with TFE. Homopolymers are obtained under extreme experimental conditions, by using polymerization pressures from 4,000 to 18,000 atm. The perfluoromethylvinylether (PMVE) homopolymer is an elastomer; the T_g is not reported. The general formula of the described vinyl ethers is the following:



wherein R⁰_F is a perfluoroalkyl radical preferably from 1 to 5 carbon atoms. A process for preparing these vinyl ethers is described in USP 3,291,843 wherein the starting acylfluoride is salfied and pyrolyzed with carbonates also in the presence of solvents. By this process undesired hydrogenated by-products are obtained.

[0008] USP 3,450,684 relates to vinyl ethers having the formula:



wherein X⁰ = F, Cl, CF₃, H and n' can range from 1 to 20. Also homopolymers obtained by UV polymerization are reported. The exemplified copolymers are not characterized by their properties at low temperatures.

[0009] USP 3,635,926 relates to the emulsion copolymerization of perfluorovinylethers with TFE, showing that the presence of -COF acylfluoride end groups makes the polymers unstable. The same phenomenon was already reported in USP 3,085,083 in the perfluorovinylether polymerization systems in solvent.

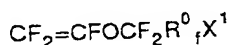
[0010] USP 3,817,960 relates to the preparation and polymerization of perfluorovinylethers having the formula



wherein n" can range from 1 to 5. The compound synthesis is complex, it requires three steps. The preparation of the starting compound CF₃O(CF₂O)_n-CF₂C(O)F is carried out by oxidation at low temperature in the presence of U.V. radiations; besides the condensation with HFPO (hexafluoropropenoxide) and the subsequent alkaline pyrolysis is necessary. No data on the above indicated properties are reported. With regard to this see USP 5,910,552

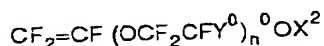
[0011] USP 3,896,179 relates to the separation of "primary" isomers of perfluorovinylethers, for example of CF₃CF₂CF₂OCF=CF₂ from the corresponding less stable "secondary" isomers CF₃-(CF₃)CFOCF=CF₂. The latter are undesired products as regards both the polymer preparation and the poor properties of the obtained polymers.

[0012] USP 4,340,750 relates to the preparation of perfluorovinylethers having the formula



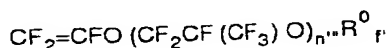
wherein R^0 is a C_1 - C_{20} perfluoroalkyl optionally containing oxygen, $\text{X}^1=\text{H}$, Cl , Br , F , COOR^0 , CONR^0R^1 wherein R^0 is a C_1 - C_{10} alkyl group and R^1 represents H or a C_1 - C_{10} alkyl group. In the preparation of these compounds an acylfluoride together with iodine and tetrafluoroethylene is used, avoiding the final step of the acylfluoride pyrolysis which comes from the perfluoro-propene epoxide, by a deiodofluorination reaction, which takes place with low yields.

[0013] USP 4,487,903 relates to the preparation of fluoroelastomeric copolymers using perfluorovinylethers having the formula:



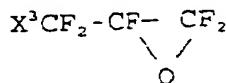
wherein n^0 ranges from 1 to 4; $\text{Y}^0=\text{F}$, Cl , CF_3 , H ; X^2 can be C_1 - C_3 perfluoroalkyl group, C_1 - C_3 ω -hydroperfluoroalkyl group, C_1 - C_3 ω -chloroperfluoroalkyl group. The polymer has a content of fluorovinylether units ranging from 15 to 50% by moles. These vinyl ethers give copolymers which at low temperatures have better properties than those of the above mentioned perfluorovinylethers PVE (perfluoropropylvinylether) and MVE type. In the patent it is disclosed that in order to have good properties at low temperature, the presence of at least two ether bonds in the side chain adjacent to the double bond is required. Furthermore from the patent it results that for n^0 values higher than 4 it is difficult to purify the monomers and the effect on the decrease of the polymer T_g is lower. Besides the reactivity of the described vinyl ethers is very low and it is difficult to obtain polymers having a high molecular weight able to give good elastomeric properties. A TFE/perfluorovinylether copolymer ($n^0=2$) 73/27 % by moles with T_g of -32°C is exemplified. However the polymer is obtained with very long reaction times (96 hours of polymerization).

[0014] EP 130,052 describes the perfluorovinylpolyether (PVPE) polymerization which leads to amorphous perfluoropolymers with a T_g ranging from -15 to -100°C . The described polymers have T_g values reaching up to -76°C ; the further T_g decrease is obtained by using perfluoropolyethers as plasticizers. In the patent copolymers and terpolymers of TFE and MVE with vinyl ethers (PVPE) having the formula



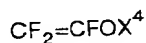
are described, wherein n'' ranges from 3 to 30 and R^0 is a perfluoroalkyl group. Due to purification difficulties, the used vinyl ethers are vinyl ether mixtures with different n'' values. According to said patent the most evident effect on the T_g decrease is shown when n'' is equal to or higher than 3, preferably higher than 4. According to the polymerization examples described in said patent the final mass of the polymer, besides the hot and under vacuum treatment, must then be washed with freon® TF in order to remove all the unreacted monomer (PVPE). From the Examples it results that the reactivity of all the described monomers (PVPE) is poor.

[0015] USP 4,515,989 relates to the preparation of new intermediates for the fluorovinylether synthesis. According to the patent the vinyl ether synthesis is improved by using an intermediate able to more easily decarboxylate. For its preparation fluoroepoxides of formula:



wherein $\text{X}^3 = \text{Cl}$, Br are used.

[0016] USP 4,619,983 describes the copolymerization of VDF with vinyl ethers having the formula:



wherein X^4 is a C_3 - C_9 oxyperfluoroalkyl radical containing from 1 to 3 oxygen atoms. The obtained polymers are not perfluorinated polymers and show a poor stability to alcohols.

[0017] USP 4,766,190 relates to the polymerization of perfluorovinylpolyethers (PVPE) similar to those of USP 4,487,903 with TFE and low perfluoropropene percentages, in order to increase the mechanical properties of the ob-

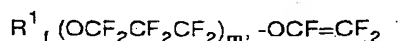
tained polymers.

[0018] EP 338,755 relates to the preparation of perfluorinated copolymers by using direct fluorination of partially fluorinated copolymers. More reactive partially fluorinated monomers are used, the obtained polymers are fluorinated with elemental fluorine. The fluorination step requires a supplementary process unit, besides in this step elemental fluorine is used, which is a highly oxidizing gas, with the consequent precautions connected to its use. Besides in the patent it is stated that in order not to compromise the fluorination reaction and the properties of the obtained polymer, using the invention process the percentage of the comonomer in the polymer cannot exceed 50% by moles.

[0019] USP 5,268,405 reports the preparation of perfluorinated rubbers having a low T_g, by the use of high viscosity perfluoropolyethers as plasticizers of perfluorinated rubbers (TFE/MVE copolymers). However during the use perfluoropolyether bleeds take place. This is true especially for the PFPE having a low molecular weight (low viscosity) : in said patent, therefore, the high viscosity PFPE use is suggested, and therefore the low viscosity PFPEs must previously be removed.

[0020] USP 5,350,497 relates to the preparation of perfluoroalkylvinylethers by fluorination with elemental fluorine of hydrofluorochloroethers and subsequent dechlorination.

[0021] USP 5,401,818 relates to the preparation of perfluorovinylethers of formula:



(wherein R¹₁ is a C₁-C₃ perfluoroalkyl radical and m' is an integer ranging from 1 to 4) and of the corresponding copolymers having improved properties at low temperature. The preparation of said perfluorovinylethers is carried out by 7 steps, some of them have very low yields, and comprise also a fluorination with elemental F₂. The reactivity of said perfluorovinylethers is anyhow low.

[0022] As it is shown from the above prior art, the perfluorovinylether synthesis generally involves a multistep process with low yields (USP 3,132,123, USP 3,450,684), with additional purifications to remove undesired isomers (USP 3,896,179) and the need to control the undesired hydrogenated by-products (USP 3,291,843). Alternatively, in the synthesis substances acting as intermediates, which are suitably prepared, and which allow to eliminate said drawbacks (USP 4,340,750, USP 4,515,989), are used.

[0023] Furthermore in some cases the vinyl ether preparation requires the fluorination with elemental fluorine of partially fluorinated intermediates (USP 5,350,497); or, to avoid synthesis and low reactivity problems of the perfluorovinylethers, fluorination of partially fluorinated polymers (EP 338,755) is suggested.

[0024] Other problems shown in the prior art relate to the low reactivity of the perfluorovinylethers, which makes it necessary the recovery of the unreacted monomers from the reaction products (UK 1,514,700), and the stability problems for the polymers having -C(O)F end groups (USP 3,635,926). These last can be furtherly transformed by suitable reactants in order to increase the stability of the fluorinated polymer (EP 178,935).

[0025] Perfluorooxyalkylvinylethers are used to confer to the fluorinated rubbers good properties at low temperatures, and specifically to lower the copolymer glass transition temperature.

[0026] By increasing the perfluorooxyalkyl units forming the side perfluorooxyalkyl substituent, the T_g of the corresponding obtainable amorphous copolymers decreases, but at the same time the vinyl ether reactivity drastically decreases, making more evident the problems previously shown for the recovery of the unreacted monomer from the polymerization products or from the polymer itself (USP 4,487,903 - EP 130,052). In some cases, where the monomer cannot be completely removed by simple stripping under vacuum, more washings must then be carried out with fluorinated solvents for completely eliminating the unreacted vinyl ethers from the polymeric mass.

[0027] The perfluoromethylvinylether (MVE) is used as comonomer in elastomeric fluoropolymers and, at higher concentrations, also in elastomeric fluoropolymers. In particular in EP 633,257 and EP 633,274 MVE is polymerized with TFE in the presence of small amounts of PVE or dioxoles to obtain polymers with improved flex life.

[0028] The amorphous copolymers of TFE with perfluoromethylvinylether have a T_g around 0°C or slightly lower (Maskomik, M. et al. "ECD-006 Fluoroelastomer - A high performance engineering material". Soc. Plast Eng. Tech. Pao. (1974), 20, 675-7).

[0029] The T_g extrapolated value of the MVE homopolymer is of about -5°C (J. Macromol. Sci.-Phys., B1(4), 815-830, Dec. 1967).

[0030] In USP 5,296,617 and 5,235,074 there is described the hypofluorite CF₂(OF)₂ reactivity towards unsaturated products, which contemporaneously leads to the formation of the dioxolane derivative and to the fluorination compound of the olefin itself. In EP 683,181 there is described the CF₂(OF)₂ reactivity towards olefins which leads to the formation of linear reaction compounds between one hypofluorite molecule and two molecules of the same olefin, for the preparation of symmetric dienes.

[0031] The Applicant has surprisingly and unexpectedly found that it is possible to solve the above technical problem as described hereinafter, by using special fluorovinylethers, which are furthermore easily synthetizable and obtainable

by a continuous process.

[0032] An object of the present invention are fluorovinylethers of general formula:



wherein R is a C₂-C₆ linear, branched or C₅-C₆ cyclic (per)fluoroalkyl group, or a C₂-C₆ linear, branched (per)fluoroalkoxy group containing from one to three oxygen atoms; when R is a fluoroalkyl or fluoroalkoxy group as above defined it can contain from 1 to 2 atoms, equal to or different from each other, selected from the following: H, Cl, Br, I; X = F, H.

[0033] The fluorovinylethers of general formula:



wherein Y = F, OCF₃; X as above defined, are preferred among the compounds of formula (I).

[0034] The perfluorovinylethers of formula:



wherein Y is as above defined, are furtherly preferred. For example the perfluorovinylether having the formula:



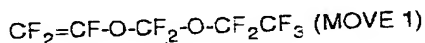
can be mentioned.

[0035] Surprisingly, the vinyl ethers according to the invention show the advantages reported hereinafter with respect to the known vinyl ethers.

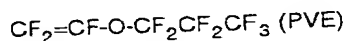
[0036] The obtainable advantages can be attributed to the -OCF₂O- unit directly bound to the ethylene unsaturation.

[0037] The T_g lowering obtained with the vinyl ethers of the invention is connected to the presence of the (-OCF₂O-) unit directly bound to the unsaturation. The T_g lowering is surprisingly so evident to be defined a primary effect.

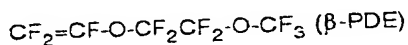
[0038] In fact if the vinyl ether of the invention with two oxygen atoms is used:



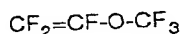
the T_g lowering is clearly higher with respect to the PVE



and to the vinyl ether having the same formula, but with the second oxygen atom in a different position and without showing the characteristic unit (-OCF₂O-)



It is surprising to notice that with respect to MVE



the β-PDE vinyl ether does not give any advantage as regards T_g.

[0039] On the contrary the primary effect of the (-OCF₂O-) unit results very clear with the vinyl ethers of the invention (MOVE).

[0040] Besides it has surprisingly been found that the (-OCF₂O-) unit bound to the ethylene unsaturation of the

vinylethers of the invention increases the vinylether reactivity drastically reducing the rearrangements to COF which cause instability.

[0041] The advantages of the polymers of the invention can be summarized as follows:

- The reactivity of the new monomers allows to prepare copolymers having a high MW (molecular weight) with a very low content of carboxylic groups or derivatives thereof such as -C(O)F, -COO-. The carboxylic group content in the copolymer with TFE has resulted of about 10 times lower than that of a copolymer prepared under the same conditions but using perfluoropropylvinylether (PVE) instead of fluorovinylethers (see the Examples). As said, the presence of a lower content of carboxylic groups, or of the corresponding derivatives (amides, esters, etc.) allows to obtain more stable polymers.
 - The reactivity of the monomers of the invention is surprisingly high (see the homopolymerization Examples).
 - The fluorovinylethers of the invention can be used as comonomers both in plastomeric (per)fluoropolymers (containing crystalline domains) and in elastomeric (per)fluoropolymers. To obtain plastomeric polymers the amount of the vinylether of the invention must be such to lead to the formation of crystalline domains, generally < 10% by moles. To obtain amorphous polymers the amount of the vinylether of the invention must be such to lead to the disappearance of the crystalline domains. The skilled man in the art can easily find the amount of the vinylether of the invention which is required for obtaining said results.
- Generally the amount of the vinylether for obtaining amorphous polymers is higher than 10% by moles, preferably in the range from about 15 to 20% by moles, or higher. In the case of copolymers having a high content of vinylether monomer, the properties at low temperature (T_g) of the polymers of the invention result clearly better with respect both to copolymers having the same MVE content (see the Examples) and also, surprisingly, with respect to copolymers where the perfluorovinylether, the oxygen atoms being equal, does not show the -OCF₂O- group directly bound to the unsaturation, as in the case of the CF₂=CFOCF₂CF₂OCF₃ (β-PDE) (see the Examples).
- Their use in the polymerization reactions with fluoroolefins allows to substantially and contemporaneously reduce two important disadvantages of the prior art: the recovery of the unreacted vinylether and the polymer instability due to the presence of carboxylic end groups.
 - A further advantage of the fluorovinylethers of the invention, as hereinafter illustrated, consists in that their preparation is carried out in a continuous plant by a limited number of steps. Furthermore the used raw materials are cheap. The following ones can for example be mentioned:

CF₂(OF)₂, CF₂=CF₂, CF₂=CFOCF₃, CHCl=CFCl, CFCI=CFCl,
CF₂=CFCI, CF₂=CFH, CF₂=CH₂, CHCl=CHCl and other olefins.

[0042] The use of these reactants is specified in the synthesis process of the vinylethers of the invention.

[0043] Polymers, homopolymers, copolymers are obtainable by polymerizing the fluorovinylethers of general formula (I) - (IV) with at least another monomer.

[0044] With copolymer, a polymer containing the vinylether of the invention and one or more comonomers, is meant.

[0045] With comonomers, fluorinated compounds having at least one polymerizable double bond C=C, optionally containing hydrogen and/or chlorine and/or bromine and/or iodine and/or oxygen, are preferably meant.

[0046] Optional comonomers which can be copolymerized are non fluorinated C₂-C₈ olefins, such as ethylene, propylene, isobutylene.

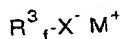
[0047] Among the usable comonomers the following can be mentioned:

- C₂-C₈ perfluoroolefins, such as tetrafluoroethylene (TFE), hexafluoropropene (HFP), hexafluoroisobutene;
- C₂-C₈ hydrogenated fluoroolefins, such as vinyl fluoride (VF), vinylidene fluoride (VDF), trifluoroethylene, CH₂=CH-R₂, perfluoroalkylethylenes, wherein R₂ is a C₁-C₆ perfluoroalkyl;
- C₂-C₈ chloro- and/or bromo- and/or iodo-fluoroolefins, such as chlorotrifluoroethylene (CTFE) and bromotrifluoroethylene;
- CF₂=CFOR₂ (per)fluoroalkylvinylethers (PAVE), wherein R₂ is a C₁-C₆ (per)fluoroalkyl, for example trifluoromethyl, bromodifluoromethyl or heptafluoropropyl;
- CF₂=CFOX^a (per)fluoro-oxyalkylvinylethers, wherein X^a is: a C₁-C₁₂ alkyl, or a C₁-C₁₂ oxyalkyl, or a C₁-C₁₂ (per)fluoroalkyl having one or more ether groups, for example perfluoro-2-propoxy-propyl. - sulphonic monomers having the structure CF₂=CFOX^bSO₂F, wherein X^b = CF₂CF₂, CF₂CF₂CF₂, CF₂CF(CF₂X^c) wherein X^c = F, Cl, Br.

[0048] The process for preparing fluorinated polymers according to the present invention can be carried out by polymerization in organic solvent as described in USP 4,864,006 and 5,182,342, herein incorporated by reference. The organic solvent is selected from the group comprising chlorofluorocarbons, perfluoropolyethers, hydrofluorocarbons and hydrofluoroethers.

[0049] The process for preparing the polymers of the present invention can be carried out also by polymerization in aqueous emulsion according to well known methods in the prior art, in the presence of a radical initiator. This can be selected for example from: inorganic peroxides (for example alkaline metal or ammonium persulphates, perphosphates, perborates or percarbonates), optionally in combination with ferrous, cuprous or silver salts, or of other easily oxidizable metals; organic peroxides (for example, disuccinylperoxide, tertbutylhydroperoxide, di-tertbutylperoxide); azocompounds (see USP 2,5-15,628 and USP 2,520,338, herein incorporated by reference). It is also possible to use organic or inorganic redox systems, such as ammonium persulphate/sodium sulphite, hydrogen peroxide/aminoiminomethanesulphonic acid.

[0050] In the reaction medium also surfactants of various type are usually present, among which the fluorinated surfactants of formula:



are particularly preferred, wherein R^3_f is a C_5-C_{16} (per)fluoroalkyl chain or a (per)fluoropolyoxyalkyl chain, X^- is $-COO^-$ or $-SO_3^-$, M^+ is selected from: H^+ , NH_4^+ , an alkaline metal ion. Among the most commonly used, ammonium perfluorooctanoate, (per)fluoropolyoxyalkylenes ended with one or more carboxylic groups, etc. can be mentioned.

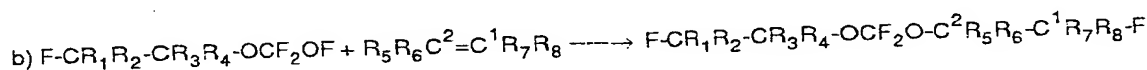
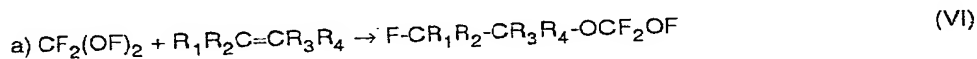
[0051] During the polymerization, known iodinated chain transfer agents can be added to the reaction medium. It is also possible to use as chain transfer agents alkaline or earth-alkaline metal iodides and/or bromides, according to USP 5,173,553, herein incorporated by reference.

[0052] Other chain transfer agents are mentioned in USP 4,766,190, herein incorporated by reference.

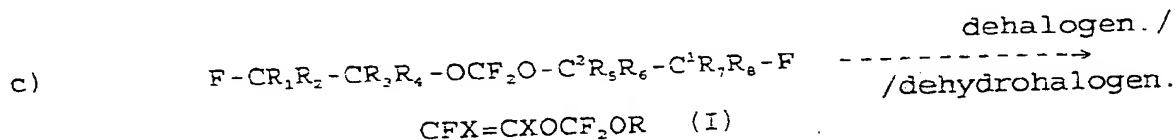
[0053] The crosslinking process of the amorphous polymers of the present invention can be carried out according to well known methods in the prior art. When, for example, one of the comonomers is vinylidene fluoride or vinyl fluoride, curing can be carried out with polyamines or aromatic polyols in the presence of suitable catalysts (accelerants) as described in USP 3,876,654, USP 4,259,463; when the monomer is perfluorinated, one generally uses the addition in amounts lower than or equal to 3% of a comonomer having a reactive site formed, for example, by Br, I, CN, OC_6F_5 , $COOR^a$ wherein R^a is an alkyl from 1 to 5 carbon atoms, or by double bonds as described in USP 5,268,405; when the polymer contains Br or I, it is cured in the presence of a peroxide or of a polyunsaturated compound as described in USP 4,948,852, USP 4,948,853, USP 4,983,697, EP 683,149.

[0054] Another object of the present invention consists in the synthesis process of the new (per)fluorovinylethers, which comprises the reaction of the hypofluorite with a fluorinated olefin of formula $R_1R_2C=CR_3R_4$ to give the intermediate hypofluorite $F-CR_1R_2-CR_3R_4-OCF_2OF$, the subsequent reaction of said compound with a second fluorinated olefin of formula $R_5R_6C=CR_7R_8$ to give the intermediate $F-CR_1R_2-CR_3R_4-OCF_2O-CR_5R_6-CR_7R_8-F$, which by dehalogenation or dehydrohalogenation leads to the new perfluorovinylethers.

The general scheme of the synthesis is the following:



(VII)



In this synthesis scheme:

- with reference to the formula of the compound (VII):

- R_1, R_4 , equal or different, are H, F; R_2, R_3 , equal or different are H, Cl under the following conditions: (1) when the final reaction is a dehalogenation $R_2, R_3 = Cl$; (2) when the final reaction is a dehydrohalogenation one of the two substituents R_2, R_3 is H and the other is Cl;

- R_5, R_6, R_7, R_8 are

- F, or one of them is a C_1 - C_4 linear or branched perfluoroalkyl group, or a C_1 - C_4 linear or branched perfluoroalkoxy group containing from one to three oxygen atoms, or R_5 and R_7 , or R_6 and R_8 , are linked each other to form with C^2 and C^1 a C_5 - C_6 cycle perfluoroalkyl group;
- when one of the R_5 to R_8 radicals is a C_2 - C_4 linear or branched fluoroalkyl, or a C_2 - C_4 linear or branched fluoroalkoxy group containing from one to three oxygen atoms, one or two of the other R_5 to R_8 are F and one or two of the remainders, equal to or different from each other, are selected from H, Cl, Br, Iodine; when the substituents selected from H, Cl, Br, Iodine are two, they are both linked to the same carbon atom; when R_5 and R_7 , or R_6 and R_8 , are linked each other to form with C^2 and C^1 a C_5 - C_6 cycle fluoroalkyl group, one of the two free substituents R_6, R_8 or R_5, R_7 is F and the other is selected from H, Cl, Br, Iodine.

- the fluoroalkene used in the reaction a) is replaceable with that of the subsequent reaction b); in this case the meanings defined for the substituents of the R_1 - R_4 group, and respectively of the R_5 - R_8 group, are interchangeable each other, with the proviso that the position of each radical of each of the two groups R_1 - R_4 and R_5 - R_8 with respect to $-OCF_2O-$ on the chain of the intermediate compound (VII), is the same which is occupied if the synthesis takes place according to the above reported scheme and the two olefins each react in the considered steps.

[0055] In the first reaction a) of the above illustrated scheme a hypofluorite gas flow $CF_2(OF)_2$, suitably diluted with an inert fluid, comes into contact, in a suitable reactor with outlet, on the bottom of the same (first reactor), with a flow of the $R_1R_2C=CR_3R_4$ olefin, optionally diluted in an inert fluid, to allow the chemical reaction a) with formation of the intermediate hypofluorite (VI). To favour the reaction stoichiometry, the reactants must be introduced into the reactor in an approximately unitary molar ratio, or with an excess of $CF_2(OF)_2$. The residence time of the mixture in the reactor can range from few hundredths of second up to about 120 seconds depending on the olefin reactivity, the reaction temperature and the presence of optional reaction solvents.

[0056] The reaction temperature can range from -40° to $-150^\circ C$, preferably from -80° to $-130^\circ C$.

[0057] The compound (VI) usually is not separated from the reaction product and it is transferred in a continuous way to the subsequent reaction described in step b).

[0058] The mixture of the products coming out from the first reactor can be heated at room temperature before being fed into the second reactor.

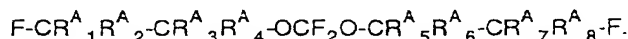
[0059] In the second reaction b) the second olefin $R_5R_6C=CR_7R_8$ pure or in solution, reacts with the product obtained in the first reaction with formation of compound (VII).

[0060] The olefin can be fed in a continuous way, so as to maintain its concentration constant in the reactor. The temperature of the reaction b) can range from -20° to $-130^\circ C$, preferably from -50° to $-100^\circ C$. The olefin concentration is higher than or equal to 0.01M, preferably the concentration is higher than 3M, more preferably also the pure compound can be used.

[0061] The solvents used in steps a) and b) are perfluorinated or chlorohydrofluorinated solvents or hydrofluorocarbons. Examples of said solvents are: CF_2Cl_2 , $CFCl_3$, CF_3CFH_2 , $CF_3CF_2CF_3$, CF_3CCl_2H , CF_3CF_2Cl .

In the reaction c) the compound (VII), dependently on the olefins used in steps a) and b), after distillation from the reaction product, is subjected to dechlorination or to dehydrochlorination to obtain the vinyl ethers of formula (I). This last step can be carried out by using reactions widely described in the prior art. The suitable selection of the substituents R_1 to R_8 in the two olefins used in the synthesis allows to obtain the vinyl ethers of the present invention.

[0062] Another object of the invention is a process wherein a hypofluorite of formula $X_1X_2C(OF)_2$ wherein X_1 and X_2 equal or different are F, CF_3 , and two fluoroalkenes of formula respectively $RA_1RA_2C=CR^A_3R^A_4$ and $RA_5RA_6C=CR^A_7R^A_8$, wherein RA_1 - RA_8 equal or different, are F, H, Cl, Br, I, $-CF_2OSO_2F$, $-SO_2F$, $-COF$, C_1 - C_5 linear or branched perfluoroalkyl or oxyperfluoroalkyl group, are reacted according to steps a) and b) excluding the dehalogenation or dehydrohalogenation step, to obtain compounds of general formula (VIII)



[0063] The following Examples are reported with the purpose to illustrate the invention and they do not limit the scope of the same.

[0064] In the Examples the thermogravimetric analysis TGA is carried out by using a $10^\circ C/min$ rate.

EXAMPLE 1

Synthesis of $\text{CF}_3\text{CF}_2\text{OCF}_2\text{OCFCICF}_2\text{Cl}$ perfluoro-1,2-dichloro-3,5-dioxaheptane.

[0065] The used reactor is of cylindrical type, with a total volume of 300 ml and is equipped with magnetic dragging mechanical stirrer, turbine with recycle of the reacting gas placed at 20 cm from the reactor top, internal thermocouple, two internal copper pipes for the reactant feeding which end at about 1 mm from the turbine, and product outlet from the bottom. In the reactor, inside of which the temperature is maintained at -114°C , 1.1 l/h (litres/hour) of $\text{CF}_2(\text{OF})_2$ and 3.3 l/h of He are introduced through one of the two inlet pipes; A flow of 1.1 l/h of $\text{CF}_2=\text{CF}_2$ and 0.7 l/h of He is maintained through the second inlet pipe. Feeding is continued for 6.6 hours.

[0066] The residence time of the transport gas in the reaction zone comprised between the outlet of the two feeding pipes in the reactor and the inlet of the discharge pipe is of about 4 sec.

[0067] On the reactor bottom the reaction products are brought to room temperature and the gaseous mixture flow, monitored by gaschromatography, is fed in a continuous way, under mechanical stirring, into a second reactor having a 250 ml volume maintained at the temperature of -70°C , equipped with mechanical stirrer, thermocouple, dipping inlet for the reacting mixture, outlet with head of inert gas. The reactor contains 72.6 g of dichlorodifluoroethylene $\text{CFCl}=\text{CF}-\text{Cl}$.

[0068] At the end of the addition of reacting gases into the second reactor, the reaction raw material is distilled by a plate column at atmospheric pressure, collecting 41.5 g of the desired product (boiling point 91°C).

[0069] The yield of perfluoro-1,2-dichloro-3,5-dioxaheptane, calculated with respect to $\text{CF}_2(\text{OF})_2$, is of 36%.

Characterization of perfluoro 1,2-dichloro-3,5-dioxaheptane.

[0070] Boiling point at atmospheric pressure: 91°C .

^{19}F -NMR spectrum in p.p.m. (with respect to $\text{CFCl}_3 = 0$):

-51.3/-53.0 (2F, O- CF_2 -O); -70.6/-72.6 (2F, C- CF_2Cl); -78.0/-78.4 (1F, O- CFCl -C); -87.8 (3F, CF_3 -C); -90.2/-91.8 (2F, C- CF_2 -O).

[0071] Mass spectrum (E.I. electronic impact), main peaks and respective intensities:

69 (48.6%); 119 (84.3%); 151 (76.8%); 153 (69.8%); 185 (100%).

[0072] IR spectrum (cm^{-1}) intensity: (w)=weak, (m)=medium,

(s)=strong, (vs)=very strong:

1407.3 (w); 1235.8 (vs); 1177.7 (vs); 929.3 (w); 847.9 (m); 1032.2 (s);

EXAMPLE 2

Synthesis of $\text{CF}_3\text{OCF}_2\text{CF}_2\text{OCF}_2\text{OCFCICF}_2\text{Cl}$ perfluoro-1,2-dichloro-3,5,8-trioxanonane (isomer A) and $\text{CF}_3\text{OCF}(\text{CF}_3)\text{OCF}_2\text{OCFCICF}_2\text{Cl}$ perfluoro-1,2-dichloro-3,5,7-trioxa-6-methyloctane (isomer B).

[0073] In a reactor identical to that used in Example 1, maintained at the same temperature of -114°C , 1.55 l/h of $\text{CF}_2(\text{OF})_2$ and 4.5 l/h of He are introduced through one of the two inlet pipes; through the second inlet pipe 1.4 l/h of $\text{CF}_2=\text{CF}-\text{OCF}_3$ and 0.7 l/h of He for 4.5 hours.

[0074] The residence time of the transport gas in the reaction zone comprised between the reactor outlet and the end of the two feeding pipes is of about 3 sec.

[0075] On the reactor bottom the reaction products are brought to room temperature and the gaseous mixture flow, monitored by gaschromatography, is fed in a continuous way, under mechanical stirring, into a second reactor identical to the one used for the same step in Example 1. Inside, where a temperature of -70°C is maintained, there are 51 g of dichlorodifluoroethylene $\text{CFCl}=\text{CF}-\text{Cl}$.

[0076] At the end of the addition of the reacting gases into the second reactor, the reaction raw material is distilled by a plate column at the reduced pressure of 250 mmHg. 50 g of a mixture formed by two isomers, respectively, isomer A) perfluoro-1,2-dichloro-3,5,8-trioxanonane and isomer B) perfluoro-1,2-dichloro-3,5,7-trioxa-6-methyloctane are collected. The mixture composition is determined by gaschromatography and is the following: isomer A 79%, isomer B 21%. The molar yield of A+B with respect to the used $\text{CF}_2(\text{OF})_2$ is 38%. The molar yield of A+B with respect to the used perfluoromethylvinylether is 42%. The isomers have been separated by preparative gaschromatography.

Characterization of products A and B

[0077] Mixture boiling point (A 79%, B 21%) at the reduced pressure of 250 mmHg: 82°C .

[0078] ^{19}F -NMR spectrum in p.p.m. (with respect to $\text{CFCl}_3=0$) of the isomer A:

-50.6/-52.4 (2F, O-CF₂-O); -70.0/-71.8 (2F, C-CF₂Cl); -77.7 (1F, O-CFCl-C); -55.3/-55.6 (3F, CF₃-OC); -90.7/-91.1 (2F, C-OCF₂-C); -90.2/-90.6 (2F, C-OC-CF₂OCOC).

[0079] ¹⁹F-NMR spectrum in p.p.m. (with respect to CFCI₃=0) of isomer B:

-50.0/-52.1 (2F, O-CF₂-O); -70.0/-71.8 (2F, C-CF₂Cl); -77.9 (1F, O-CFCl-C); -54.6/-54.9 (3F, CF₃OC); -85.7/-86.1 (3F, OC(CF₃)O); -100.3/-101.0 (1F, OCF(C)O).

[0080] Mass spectrum (electronic impact) main peaks and respective intensities:

Product A:

69 (50); 119 (100); 151 (50); 185 (42); 251 (38);

Product B:

69 (96); 97 (50); 135 (42); 151 (92); 185 (100).

[0081] IR spectrum (cm⁻¹), intensity of the mixture A 79%, B 21%:

(w)=weak, (m)=medium, (s)=strong, (vs)=very strong:

1388 (w); 1288 (vs); 1233 (vs); 1151 (vs); 1104 (vs); 846 (m); 1032 (s); 685 (w).

EXAMPLE 3

Synthesis of CF₃OCF₂CF₂OCF₂OCHClCHFCI perfluoro-1,2-dichloro-1,2-dihydro-3,5,8-trioxanonane (isomer C) and CF₃OCF(CF₃)OCF₂OCHClCHFCI perfluoro-1,2-dichloro-1,2-dihydro-3,5,7-trioxa-6-methyloctane (isomer D).

[0082] In a reactor identical to that used in Example 1, maintained at the temperature of -112°C, 1.55 l/h of CF₂(OF)₂ and 4.5 l/h of He are introduced through one of the two inlet pipes; through the second inlet pipe 1.4 l/h of CF₂=CF-OCF₃ and 0.7 l/h of He for 5 hours.

[0083] The residence time of the transport gas in the reaction zone comprised between the reactor outlet and the end of the two feeding pipes is of about 3 sec.

[0084] On the reactor bottom the reaction products are brought to room temperature and the gaseous mixture flow, monitored by gaschromatography, is fed in a continuous way, under mechanical stirring, into a second reactor identical to the one used for the same step in Example 1. Inside, the temperature is of -70°C and there are 50 g of 1,2-dichloroethylene CClH=CClH and 50 g of CFCI₃.

[0085] At the end of the addition of the reacting gases into the second reactor, after distillation of the solvent at room pressure, the reaction raw material is distilled by a plate column at the reduced pressure of 100 mmHg. 43.5 g of the mixture of the desired products (isomer C 78%, isomer D 22%, determined by gaschromatography) are collected. The molar yield of C+D with respect to the used CF₂(OF)₂ is 33%. The isomers have been separated by preparative gaschromatography.

Characterization of products C and D

[0086] Mixture boiling point (C 78%, D 22%) at the reduced pressure of 100 mmHg: 71°C.

[0087] ¹⁹F-NMR spectrum in p.p.m. (with respect to CFCI₃ = 0) of the isomer C perfluoro-1,2-dichloro-1,2-dihydro-3,5,8-trioxanonane:

-56.0/-57.2 (2F, O-CF₂-O); -143.2/-146.0 (1F, C-CHFCI); -55.8 (3F, CF₃-OC); -91.0/-91.4 (2F, C-OCF₂-C); -90.3/-90.5 (2F, C-OC-CF₂OCOC).

[0088] ¹⁹F-NMR spectrum in p.p.m. (with respect to CFCI₃=0) of the isomer D perfluoro-1,2-dichloro-1,2-dihydro-3,5,7-trioxa-6-methyloctane:

-56.0/-57.2 (2F, O-CF₂-O); -143.2/-146.0 (1F, C-CHFCI); -54.9/-55.1 (3F, CF₃-OC); -86.2/-86.3 (3F, OC(CF₃)O); -100.5/-101.0 (1F, OCF(C)O).

[0089] ¹H spectrum in p.p.m. (with respect to TMS) of the isomers C and D: 6.28/6.05 (1H -CHFCI); 6.02/5.95 (1H -CHCl-)

[0090] Mass spectrum (electronic impact), main peaks and respective intensities %:

69 (84); 119 (100); 185 (51.1); 251 (84); 281 (15.8); 283 (4.8); 347 (5.7); 349 (1.7).

[0091] IR spectrum (cm⁻¹) intensity: (w)=weak, (m)=medium, (s)=strong, (vs)=very strong:

3001.0 (w); 2920.9 (w); 2850.9 (w); 1286.3 (vs); 1233.7 (vs); 1125.5 (vs); 1081.8 (s); 1047.9 (s); 815.9 (m); 766.3 (m).

EXAMPLE 4

Dehalogenation of perfluoro 1,2-dichloro-3,5-dioxaheptane

[0092] In a 25 ml three-necked flask, equipped with mechanical stirrer, thermometer, dropping funnel, distillation column equipped with water refrigerant and collecting trap maintained at -78°C and connected to a mechanical vacuum pump, 150 ml of DMF, 15 g of Zn in powder, 0.5 g of K_2CO_3 and 100 mg of I_2 are introduced. The internal temperature is brought to 80°C and 50 g of perfluoro-1,2-dichloro-3,5-dioxaheptane are added drop by drop. When the addition is over the mixture is allowed to react for about 30 minutes. At the end the internal pressure gradually brought from starting 760 mmHg to 300 mmHg. After about 20 minutes the collecting trap containing 34.2 g of perfluoro-3,5-dioxa-1-heptene (MOVE 1) is disconnected.

[0093] The dehalogenation yield is 85%.

Characterization of perfluoro-3,5-dioxa-1-heptene (MOVE 1)

[0094] Boiling point at atmospheric pressure: 41.9°C .

[0095] ^{19}F -NMR spectrum in p.p.m. with respect to $\text{CFCl}_3=0$:

-56.8 (2F, O- CF_2 -O); -87.2 (3F, CF_3 -C); -90.6 (2F, C- CF_2 -O); -114 (1F, O-C=C-F); -121.8 (1F, O-C=CF); -137 (1F, O-C-F=C);

[0096] Mass spectrum (electronic impact), main peaks and respective intensities: 69 (66.5%); 119 (100%); 147 (85.4%); 185 (89.4%); 216 (67.3%); 282 (8.2%).

[0097] IR spectrum (cm^{-1}) intensity: (w)=weak, (m)=medium, (s)=strong, (vs)=very strong:

1839.5 (m); 1407.6 (w); 1307.4 (vs); 1245.8 (vs); 1117.4 (vs); 907.2 (m); 846.0 (m).

EXAMPLE 5

Dehalogenation of the isomer mixture A+B obtained in Example 2 (perfluoro-1,2-dichloro-3,5,8-trioxanonane $\text{CF}_3\text{OCF}_2\text{CF}_2\text{CF}_2\text{OCFCICF}_2\text{Cl}$ + perfluoro-1,2-dichloro-3,5,7-trioxa-6-methyloctane $\text{CF}_3\text{OCF}(\text{CF}_3)\text{OCF}_2\text{OCFCICF}_2\text{Cl}$).

[0098] In a 250 ml flask equipped as described in the previous Example 4, 110 ml of DMF, 10 g of Zn in powder and 0.3 ml of Br_2 are introduced. The internal temperature is brought to 75°C and 30.3 g of the binary mixture A+B separated in the previous Example 2 are added drop by drop. When the addition is over the mixture is allowed to react for about 3 hours. At the end the internal pressure is gradually lowered from 760 mmHg to 200 mmHg at -79°C . After about 30 minutes the collecting trap is disconnected. The corresponding content, which is washed with water, is recovered. At the end 24.0 g of a mixture formed for 79% (gaschromatographic determination) by perfluoro-3,5,8-trioxa-1-nonene (MOVE 2) $\text{CF}_3\text{OCF}_2\text{CF}_2\text{OCF}_2\text{OCF}=\text{CF}_2$ (isomer A') and for 21% by perfluoro-3,5,7-trioxa-6-methyl-1 octene (MOVE 2a) $\text{CF}_3\text{OCF}(\text{CF}_3)\text{OCF}_2\text{O}-\text{CF}=\text{CF}_2$ (isomer B') are obtained, which are then separated by preparative gaschromatography.

Characterization of products A' and B'

[0099] Boiling range of the isomer mixture at atmospheric pressure: $72.5^{\circ}-74.5^{\circ}\text{C}$.

[0100] ^{19}F -NMR spectrum in p.p.m. (with respect to $\text{CFCl}_3=0$) of the isomer A':

-55.9 (3F, CF_3 -O); -56.9 (2F, O- CF_2 -O); -90.8 (2F, C- CF_2 -O); -91.2 (2F, O- CF_2 -C); -114 (1F, O-C=C-F); -121.8 (1F, O-C=CF); -137 (1F, O-CF=C)

[0101] ^{19}F -NMR spectrum in p.p.m. (with respect to $\text{CFCl}_3=0$) of the isomer B':

-55.9 (3F, CF_3 -O); -56.2 (2F, O- CF_2 -O); -86.4 (3F, CF_3 -C); -100.9 (1F, CF); -114 (1F, O-C=C-F); -122 (1F, O-C=CF); -137 (1F, O-CF=C).

[0102] Mass spectrum (electronic impact), main peaks and respective intensities of the isomer A': 69 (74); 81 (18); 119 (100); 147 (59); 185 (26); 251 (21);

[0103] Mass spectrum (electronic impact), main peaks and respective intensities of the isomer B': 81 (37); 69 (80); 97 (47); 119 (36); 147 (100); 185 (19).

[0104] IR spectrum (cm^{-1}), intensity: (w)=weak, (m)=medium,

(s)=strong, (vs)=very strong, 1839 (m); 1343 (s); 1248 (vs); 1145 (vs); 918 (m); 889 (m).

EXAMPLE 6

Dehalogenation of the isomers C+D mixture obtained in Example 3 (CF₃OCF₂CF₂OCF₂OCHClCHFCI perfluoro-1,2-dichloro-1,2-dihydro-3,5,8-trioxanonane (isomer C)+ CF₃OCF(CF₃)OCF₂OCHClCHFCI perfluoro-1,2-dichloro-1,2-dihydro-3,5,7-trioxa-6-methyloctane (isomer D)).

[0105] In a 500 ml three-necked flask, equipped with mechanical stirrer, thermometer, dropping funnel, distillation column having a water refrigerant and a collecting trap maintained at the temperature of -78°C, 250 ml of DMF, 30 g of zinc in powder and 300 mg of I₂ are introduced.

[0106] The temperature is brought to 100°C and 56.9 g of the isomer mixture obtained in Example 3 are added drop by drop.

[0107] When the addition is over the reactor internal temperature is brought to 120°C and stirring is maintained for 24 hours. At the end the reaction product, which contains traces of solvent and which is collected in the trap maintained at -78°C, is distilled. After washing with water 35 g of a mixture of perfluoro-1,2-dihydro-3-5-8-trioxa-1-nonene (isomer C', 79% by moles) and of perfluoro-1,2-dihydro-3-5-7-trioxa-5-methyl-1-octene (isomer D', 21 % by moles) are recovered. The isomers are separated by preparative gaschromatography.

[0108] The dehaloagenation reaction yield is 76%.

Characterization of products C' and D'

[0109] Boiling range of the mixture of isomers C' 79%, D' 21% at atmospheric pressure: 90.0°-92.0°C.

[0110] ¹⁹F-NMR spectrum in p.p.m. (with respect to CFCl₃=0) of the isomer C' perfluoro-1,2-dihydro-3,5,8-trioxa-1-nonene:

-55.7 (3F, CF₃-O); -57.3 (2F, O-CF₂-O); -90.9 (2F, C-CF₂-O); -91.2 (2F, O-CF₂-C); -149.3/-150.0 (1F, O-C=C-F).

[0111] ¹⁹F-NMR spectrum in p.p.m. (with respect to CFCl₃=0) of the isomer D' perfluoro-1,2-dihydro-3,5,7-trioxa-6-methyl-1-octene:

-55.0 (3F, CF₃-O); -56.9 (2F, O-CF₂-O); -86.2 (3F, CF₃-C); -101.0 (1F, CF); -149.3/-150.0 (1F, O-C=C-F)

[0112] Mass spectrum (electronic impact), main peaks and respective intensities %:

69 (82); 119 (100); 185 (29); 246 (25); 251 (20); 312 (43).

[0113] IR spectrum (cm⁻¹) intensity of the isomer mixture (C' 79%, D' 21%) : (w) =weak, (m) =medium, (s) =strong, (vs) =very strong:

3140 (w) ; 1722 (w) ; 1695 (w) ; 1402 (m) ; 1281 (vs); 1237 (vs); 1147 (vs) ; 1106 (vs) ; 1030 (m).

EXAMPLE 7

Homopolymerization of perfluoro-3,5-dioxa-1-heptene (MOVE 1).

[0114] In a glass reactor for polymerizations, having a 20 ml volume, equipped with magnetic stirring and with an inlet for the reactant feeding and discharge, 60 µl of perfluoropropionylperoxide at 3% by weight in CFCl₂CF₂Cl and 3 g of MOVE 1 are in sequence introduced. The so charged reactor is brought to the temperature of -196°C, evacuated, brought to room temperature, the all twice. At the end of the degassing operations the reactor is thermostated at the temperature of 30°C and the mixture is allowed to react under these conditions for two days under magnetic stirring.

[0115] The reaction raw material which is finally recovered appears as a slightly viscous, transparent, colourless and homogeneous solution.

[0116] After distillation of the unreacted monomer, and subsequent stripping under vacuum at 150°C for 3 hours, 180 mg of the polymer are separated.

[0117] The IR analysis of the obtained polymer shows that, in the spectrum, absorption bands in the zone of the fluorinated double bonds are absent.

[0118] The ¹⁹F-NMR analysis carried out on the polymer dissolved in C₆F₆ is in accordance with the homopolymer structure having a molecular weight of 50,000. The analysis does not show the presence of unreacted monomer.

[0119] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The polymer T_g, determined by DSC, is -35.4°C. The thermogravimetric analysis (TGA) shows a weight loss of 2% at 332°C and of 10% at 383°C.

EXAMPLE 8

Copolymer between perfluoro-3,5,8-trioxa-1-nonene $\text{CF}_3\text{OCF}_2\text{CF}_2\text{OCF}_2\text{OCF}=\text{CF}_2$ (MOVE 2) and perfluoro-3,5,7-trioxa-6-methyl-1-octene $\text{CF}_3\text{OCF}(\text{CF}_3)\text{OCF}_2\text{O}-\text{CF}=\text{CF}_2$ (MOVE 2a).

[0120] In a reactor having the same characteristics as that described in Example 7, 150 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$ and 3.2 g of a mixture prepared according to the process of Example 5 and containing 83% MOVE 2 and 17% MOVE 2a, are introduced. The reactor is then evacuated, cooled, and the subsequent reaction carried out as described in the previous Example 7.

[0121] The reaction raw material appears as a slightly viscous, transparent, colourless and homogeneous solution. The monomers which have not reacted are distilled and a stripping under vacuum at 150°C for 3 hours is in sequence carried out. Finally 350 mg of the polymer are separated.

[0122] The IR analysis shows that, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds are absent.

[0123] The ^{19}F -NMR analysis is in accordance with the copolymer structure having an average molecular weight of 35 000 and a MOVE 2/MOVE 2a content equal to the percentages of the reacting mixture; unreacted monomers are not evident.

[0124] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The polymer T_g , determined by DSC, is -52.6°C. The thermogravimetric analysis (TGA) shows a weight loss of 2% at 280°C and of 10% at 327°C.

EXAMPLE 9

Crystalline copolymer between MOVE 1 and TFE.

[0125] A 5 l steel AISI 316 autoclave with stirrer working at 650 rpm has been used. After the vacuum has been effected, 3 l of demineralized water, 15.70 g of MOVE 1 and the microemulsion prepared according to the procedure described in USP 4,864,006 are in sequence introduced, so as to have a concentration of 2 g of surfactant/l of water.

[0126] The autoclave is heated up to 75°C and then 0.32 bar of ethane are introduced. A gaseous mixture in a molar ratio of 54.55 TFE/MOVE 1 is pumped by a compressor until having inside the autoclave a pressure of 21 absolute bar.

[0127] The composition of the gaseous mixture present in the autoclave top is analyzed by gaschromatography.

[0128] Before the reaction starting the gaseous phase results to be formed by the following molar percentages of the reactants: 93.1% TFE, 5.5% MOVE 1 and 1.4% Ethane. The reaction is triggered by feeding in a continuous way by a metering pump a potassium persulphate 0.0031 molar solution at a flow rate of 88 ml/h.

[0129] The pressure is maintained constant by feeding the monomer mixture. The polymer synthesis is stopped after 742 g of mixture have been fed in total.

[0130] The reactor is cooled at room temperature, the emulsion is discharged and the coagulation is induced by HNO_3 (65%) addition.

[0131] The polymer is separated, washed with water and dried at 220°C.

[0132] The IR analysis shows the presence of very small absorption bands in the carboxyl zone, whose intensity results to be half of the one obtained from a TFE/PVE copolymer film having the same thickness, prepared according to the comparative Example 3. MFI according to ASTM D 1238-52T was 4.4. The polymer therefore results thermally more stable (see the comparative Example hereunder).

EXAMPLE 10

Amorphous copolymer between MOVE 1 and TFE.

[0133] In an AISI-316 polymerization reactor having a 40 ml volume, equipped with magnetic stirring, pressure transducer and an inlet for the reactant feeding and discharge, 250 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$, 9.8 mmoles of MOVE 1 and 18 mmoles of tetrafluoroethylene are introduced.

[0134] The reactor is cooled to the temperature of -196°C, evacuated, then brought to room temperature and cooled again, the all twice.

[0135] At the end of the degassing operations the reactor is thermostated at the temperature of 30°C and the reaction mixture maintained under magnetic stirring. The internal pressure decreases from 6.4 atm to 4.7 atm in about 8 hours (reaction time).

[0136] After distillation of the unreacted monomers, and polymer stripping under vacuum for 3 hours at 150°C, 1,100 mg of polymer are recovered, which appears as a transparent and colourless rubber.

[0137] By ^{19}F -NMR analysis of the polymer dissolved under heating in C_6F_6 it is determined that the MOVE 1 molar percentage in the polymer is 24%.

[0138] The IR analysis does not show, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds, and shows the presence of very small absorption bands in the zone of the carboxyl signals. The intensity of these signals, compared with the similar ones obtained from a film having the same thickness obtained with the polymer of the comparative Example 1, is equal to about 1/10 of these latter.

[0139] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The T_g determined by DSC is -21.4°C .

[0140] The TGA shows a weight loss of 2% at 450°C and of 10% at 477°C . The polymer therefore results thermally more stable (see the comparative Example hereunder) with respect to the comparative Example (see afterwards).

[0141] The polymer intrinsic viscosity measured at 30°C in Fluorinert® FC-75, is 35.5 ml/g.

EXAMPLE 11

Amorphous copolymer between MOVE 1 and TFE.

[0142] In an AISI-316 polymerization reactor identical to that described in the previous Example 10, 250 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$, 9.75 mmoles of MOVE 1 and 9 mmoles of tetrafluoroethylene are in sequence introduced.

[0143] The procedure already described in the previous Example 10 is followed until the thermostating step at the temperature of 30°C under magnetic stirring. During the reaction the internal pressure decreases from 3.4 atm to 2.9 atm in about 8 hours.

[0144] At the end the unreacted monomers are distilled and the polymer is stripped under vacuum at 150°C for 3 hours.

[0145] 480 mg of the polymer are separated.

[0146] By ^{19}F -NMR analysis of the polymer dissolved under heating in C_6F_6 it is determined that the MOVE 1 molar percentage in the polymer is 39%.

[0147] The IR analysis shows that, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds are absent.

[0148] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The T_g determined by DSC is -29.8°C .

[0149] The TGA shows a weight loss of 10% at 435°C .

EXAMPLE 12

Amorphous copolymer between MOVE 1 and $\text{CF}_2=\text{CH}_2$

[0150] In a polymerization reactor identical to that described in Example 10, 250 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$, 10 mmoles of MOVE 1 and 18 mmoles of VDF are in sequence introduced.

[0151] The procedure already described in the previous Example 10 is followed until the thermostating step at the temperature of 30°C under magnetic stirring. The internal pressure decreases from 6.8 atm to 5.0 atm during the reaction (about 8 hours).

[0152] After distillation of the unreacted monomers, and subsequent polymer stripping under vacuum at 150°C for 3 hours, 1,600 mg of the polymer are separated, appearing as a transparent and colourless rubber.

[0153] By the ^{19}F -NMR analysis carried out on the polymer dissolved in C_6F_6 it is determined that the MOVE 1 molar percentage in the polymer is 40%.

[0154] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The T_g determined by DSC, is -47°C .

[0155] The TGA shows a weight loss of 2% at 428°C and of 10% at 455°C .

EXAMPLE 13

Amorphous terpolymer MOVE 2/MOVE 2a/TFE.

[0156] In a polymerization reactor identical to that described in Example 10, 100 μl of perfluoropropionylperoxide at 6% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$, 10 mmoles of a MOVE 2 (83%) and MOVE 2a (17%) mixture synthesized according to the process of Example 5, and 18 mmoles of tetrafluoroethylene (TFE) are in sequence introduced.

[0157] The procedure already described in the previous Example 10 is then followed until thermostating at the tem-

perature of 30°C under magnetic stirring. The internal pressure decreases from 6.1 atm to 3.9 atm during the reaction (about 8 hours).

[0158] After distillation of the unreacted monomers and polymer stripping under vacuum at 150°C for 3 hours, 1,131 mg of the polymer are separated.

[0159] By the ^{19}F -NMR analysis carried out on the polymer dissolved in C_6F_6 it results that the total molar percentage of the MOVE 2 + MOVE 2a perfluorovinylethers in the polymer is 22%; the MOVE 2/MOVE 2a ratio by moles in the polymer is 83/17 and it is equal to that of the starting fed mixture.

[0160] The presence of unreacted monomers is not evident.

[0161] The IR analysis does not show, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds, and it shows the presence of very small absorption bands in the zone of the carboxyl signals. The intensity of these signals, compared with the similar ones obtained from a film having the same thickness obtained with the polymer of the comparative Example 1, is equal to about 1/10 of the latter.

[0162] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The T_g determined by DSC, is -37.5°C.

[0163] The TGA shows a weight loss of 10% at 473°C.

[0164] The polymer intrinsic viscosity measured at 30°C in Fluorinert® FC-75, is 40.0 ml/g.

EXAMPLE 14

Amorphous terpolymer MOVE 2/MOVE 2a/TFE.

[0165] In a polymerization reactor identical to that described in Example 10, 100 μl of perfluoropropionylperoxide at 6% by weight in $\text{CFCl}_2\text{CF}_2\text{Cl}$, 9.7 mmoles of the MOVE 2 (83%) and MOVE 2a (17%) mixture synthesized according to the process of Example 5, and 10 mmoles of tetrafluoroethylene (TFE) are in sequence introduced.

[0166] The procedure already described in the previous Example 10 is then followed until the thermostating step at the temperature of 30°C under magnetic stirring. The internal pressure decreases from 3.6 atm to 2.7 atm during the reaction course (about 8 hours).

[0167] After distillation of the unreacted monomers and polymer stripping under vacuum at 150°C for 3 hours 652 mg of polymer are separated.

[0168] By the ^{19}F -NMR analysis carried out on the polymer dissolved in C_6F_6 it results that the total molar percentage of the MOVE 2 + MOVE 2a perfluorovinylethers in the polymer is 37%; the MOVE 2/MOVE 2a molar ratio in the polymer is 83/17 and it is equal to that of the starting fed mixture.

[0169] The presence of unreacted monomers is not evident.

[0170] The IR analysis does not show, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds.

[0171] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The T_g determined by DSC, is -44.5°C.

[0172] The TGA shows a weight loss of 10% at 451°C.

[0173] The polymer intrinsic viscosity measured at 30°C in Fluorinert® FC-75, is 16.7 ml/g.

EXAMPLE 15

Amorphous copolymer between perfluoro-1,2-dihydro-3,5,8-trioxa-1-nonene (H-MOVE 2) and perfluoro-3,5,7-trioxa-6-methyl-1-octene (H-MOVE 2a) with molar ratio 88/12.

[0174] In a reactor identical to that described in Example 7, 200 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{-CF}_2\text{Cl}$ and 3.1 g of a H-MOVE 2/H-MOVE 2a 88/12 mixture are introduced.

[0175] The procedure described in Example 7 is followed.

[0176] The recovered reaction raw material appears as a slightly viscous, transparent, colourless and homogeneous solution.

[0177] After distillation of the unreacted monomer and subsequent stripping under vacuum at 150°C for 3 hours, 120 mg of polymer are separated.

[0178] The IR analysis of the obtained polymer shows that, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds are absent.

[0179] The ^{19}F -NMR analysis is in accordance with the copolymer structure having a content of monomers H-MOVE 2 and H-MOVE 2a equal to the H-MOVE 2 and H-MOVE 2a percentages in the reacting mixture. The analysis does not show the presence of unreacted monomers.

[0180] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The

polymer T_g determined by DSC, is -58.0°C . The thermogravimetric analysis (TGA) shows a weight loss of 10% at 307°C .

EXAMPLE 16

5 Terpolymer H-MOVE 2/H-MOVE 2a/TFE.

[0181] In a reactor similar to that described in Example 10, 100 μl of perfluoropropionylperoxide at 6% by weight in $\text{CFCl}_2\text{-CF}_2\text{Cl}$ and 5 mmoles of a H-MOVE 2 (88%) and H-MOVE 2a (12%) mixture and 18 mmoles of tetrafluoroethylene, are introduced.

10 [0182] The same procedure described in Example 10 is followed.

[0183] At the end of the degassing, the reactor is thermostated at the temperature of 30°C under magnetic stirring. The internal pressure decreases from 6.8 atm to 6.5 atm in about 6 hours (reaction time).

[0184] After distillation of the unreacted monomers, and polymer stripping under vacuum at 150°C for 3 hours, 300 mg of the polymer are separated.

15 [0185] By ^{19}F -NMR analysis of the polymer dissolved under heating in C_6F_6 it is calculated that the molar percentage of the perfluorovinylethers (H-MOVE 2 + H-MOVE 2a) contained in the polymer is 33%. The H-MOVE 2/H-MOVE 2a molar ratio in the polymer is equal to the H-MOVE 2/H-MOVE 2a molar ratio of the fed mixture. Unreacted monomers are not evident.

20 [0186] The IR analysis does not show, in the polymer spectrum, absorption bands in the zone of the fluorinated double bonds.

[0187] The DSC graph does not show any melting endothermic curve wherefore the polymer is amorphous. The T_g determined by DSC, is -44.5°C .

[0188] The TGA shows a weight loss of 10% at 450°C .

25 EXAMPLE 1 (comparative)

Copolymer PVE/TFE.

30 [0189] In a polymerization reactor identical to that described in Example 10, 250 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{-CF}_2\text{Cl}$, 9.8 mmoles of PVE and 18 mmoles of tetrafluoroethylene, are in sequence introduced.

[0190] The procedure already described in the previous Example 10 is followed until thermostating at the temperature of 30°C under magnetic stirring. The reaction time is of eight hours.

[0191] After distillation of the unreacted monomers and stripping under vacuum at 150°C for 3 hours, 540 mg of the polymer are recovered.

35 [0192] By the ^{19}F -NMR analysis carried out on the polymer dissolved in C_6F_6 it is calculated that the PVE molar percentage in the polymer is 23%.

[0193] The IR analysis shows that, in the polymer spectrum, there are absorption bands in the carboxyl zone, whose intensity is 10 times higher than that obtained from a MOVE 1/TFE copolymer film prepared according to Example 10, and having the same thickness.

40 [0194] The DSC graph does not show any melting endothermic curve, wherefore the polymer is amorphous. The TGA shows a weight loss of 2% at 427°C and of 10% at 463°C . The T_g , determined by DSC, is $+15^\circ\text{C}$.

[0195] The polymer intrinsic viscosity, measured at 30°C in Fluorinert® FC-75, is 51 ml/g.

EXAMPLE 2 (comparative)

45 Copolymer between β -PDE ($\text{CF}_3\text{OCF}_2\text{CF}_2\text{OCF}=\text{CF}_2$)/TFE.

[0196] In a polymerization reactor identical to that described in Example 10, 250 μl of perfluoropropionylperoxide at 3% by weight in $\text{CFCl}_2\text{-CF}_2\text{Cl}$, 10 mmoles of β -PDE and 18 mmoles of tetrafluoroethylene, are in sequence introduced.

50 [0197] The procedure described in the previous Example 10 is followed until the thermostating step at the temperature of 30°C under magnetic stirring.

[0198] By the ^{19}F -NMR analysis carried out on the polymer purified from the monomers by the processes described in the previous Examples, it is calculated that the molar percentage of β -PDE in the polymer is 23%.

55 [0199] The DSC graph does not show any melting endothermic curve wherefore the polymer is amorphous. The T_g , determined by DSC, is -4.8°C .

[0200] This T_g value is clearly higher than those obtainable with the vinyl ethers of the invention (see the above Examples).

EXAMPLE 3 (comparative)Crystalline copolymer PVE/TFE (PFA).

[0201] One operates as in Example 9 except that in this case the perfluoropropylvinylether (PVE) is used instead of α -PDE to obtain a copolymer having MFI equal to that of the Example 9.

[0202] The IR analysis shows absorption bands in the carboxyl zone, whose intensity is the double of that obtained from a TFE/MOVE 1 copolymer film having an equal thickness prepared according to Example 9.

Claims

1. Fluorovinylethers having the following formula:



wherein R is a C_2 - C_6 linear, branched or C_5 - C_6 cyclic (per)fluoroalkyl group, or a C_2 - C_6 linear, branched (per)fluoroalkoxyalkyl group containing from one to three oxygen atoms; when R is a fluoroalkyl or fluoroalkoxyalkyl group as above defined it can contain from 1 to 2 atoms, equal to or different from each other, selected from the following: H, Cl, Br, I; X = F, H.

2. Fluorovinylethers according to claim 1, having the formula:



wherein Y = F, OCF_3 ; X as above defined.

3. Fluorovinylethers according to claims 1 and 2, having the formula:



wherein Y is as above defined.

4. A fluorovinylether according to claims from 1 to 3, having the formula:



5. Homopolymers and polymers obtainable by polymerizing the fluorovinylethers of claims 1-4 with at least another polymerizable monomer.

6. Copolymers according to claim 5, wherein the comonomers are fluorinated compounds having at least one polymerizable double bond $\text{C}=\text{C}$, optionally containing hydrogen and/or chlorine and/or bromine and/or iodine and/or oxygen.

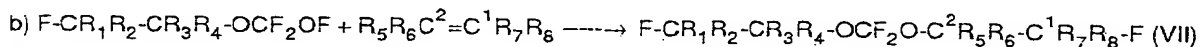
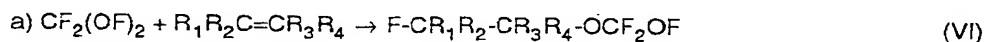
7. Copolymers according to claims 5 and 6, wherein optional copolymerizable comonomers are non fluorinated olefins C_2 - C_8 .

8. Copolymers according to claims from 5 to 7, wherein the comonomers are selected from the following:

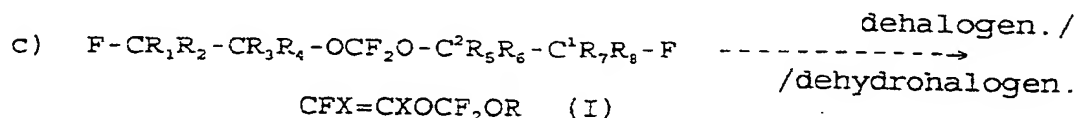
- C_2 - C_8 perfluoroolefins, preferably tetrafluoroethylene (TFE), hexafluoropropene (HFP), hexafluoroisobutene;
- C_2 - C_8 hydrogenated fluoroolefins, preferably vinyl fluoride (VF), vinylidene fluoride (VDF), trifluoroethylene, $\text{CH}_2=\text{CH}-\text{R}^2$ perfluoroalkylethylenes, wherein R^2 is a C_1 - C_6 perfluoroalkyl;
- C_2 - C_8 chloro- and/or bromo- and/or iodo-fluoroolefins, preferably chlorotrifluoroethylene (CTFE) and bromo-

- trifluoroethylene;
- $\text{CF}_2=\text{CFOR}^2$ (per)fluoroalkylvinylethers (PAVE), wherein R^2 is a $\text{C}_1\text{-C}_6$ (per)fluoroalkyl, preferably trifluoromethyl, bromodifluoromethyl or heptafluoropropyl;
 - $\text{CF}_2=\text{CFOX}^a$ (per)fluoro-oxyalkylvinylethers, wherein X^a is: a $\text{C}_1\text{-C}_{12}$ alkyl, or a $\text{C}_1\text{-C}_{12}$ oxyalkyl, or a $\text{C}_1\text{-C}_{12}$ (per) fluoroalkyl having one or more ether groups, preferably perfluoro-2-propoxy-propyl;
 - sulphonic monomers having the structure $\text{CF}_2=\text{CFOX}^b\text{SO}_2\text{F}$, wherein $\text{X}^b = \text{CF}_2\text{CF}_2, \text{CF}_2\text{CF}_2\text{CF}_2, \text{CF}_2\text{CF}(\text{CF}_2\text{X}^c)$ wherein $\text{X}^c = \text{F, Cl, Br}$.

9. Polymers according to claims from 5 to 8, wherein the (per)fluoro polymers are elastomeric ones since they contain an amount of vinylether of claims 1-4 which lead to the formation of crystalline zones.
10. Polymers according to claims from 5 to 8, wherein the (per)fluoro polymers are elastomeric ones since they contain an amount of vinylether of claims 1-4 to obtain amorphous polymers, i.e. such as to lead to the disappearance of the crystalline zones.
11. Polymers according to claim 10, wherein the amount of vinylether of claims 1-4 is in the range from about 15 to 20% by moles.
12. A synthesis process of the (per)fluorovinylethers of claims 1-4, comprising the initial reaction of hypofluorite with a fluorinated olefin having the formula $\text{R}_1\text{R}_2\text{C}=\text{CR}_3\text{R}_4$ to give the intermediate hypofluorite $\text{F-CR}_1\text{R}_2\text{-CR}_3\text{R}_4\text{-OCF}_2\text{OF}$, the subsequent reaction of this compound with a second fluorinated olefin of formula $\text{R}_5\text{R}_6\text{C}=\text{CR}_7\text{R}_8$ to give the intermediate $\text{F-CR}_1\text{R}_2\text{-CR}_3\text{R}_4\text{-OCF}_2\text{O-CR}_5\text{R}_6\text{-CR}_7\text{R}_8\text{-F}$, which by subsequent dehalogenation or dehydrohalogenation leads to the obtainment of the new perfluorovinylethers, according to the scheme:



(VII)



wherein:

- in the compound (VII) :

- R_1, R_4 , equal or different, are H, F; R_2, R_3 , equal or different are H, Cl under the following conditions: (1) when the final reaction is a dehalogenation $\text{R}_2, \text{R}_3 = \text{Cl}$, (2) when the final reaction is a dehydrohalogenation one of the two substituents R_2, R_3 is H and the other is Cl;
- $\text{R}_5, \text{R}_6, \text{R}_7, \text{R}_8$ are :
 - F, or one of them is a $\text{C}_1\text{-C}_4$ linear or branched perfluoroalkyl group, or a $\text{C}_1\text{-C}_4$ linear or branched perfluoroalkoxy group containing from one to three oxygen atoms, or R_5 and R_7 , or R_6 and R_8 , are linked each other to form with C^2 and C^1 a $\text{C}_5\text{-C}_6$ cycle perfluoroalkyl group;
 - when one of the R_5 to R_8 radicals is a $\text{C}_2\text{-C}_4$ linear or branched fluoroalkyl, or a $\text{C}_2\text{-C}_4$ linear or branched fluoroalkoxy group containing from one to three oxygen atoms, one or two of the other R_5 to R_8 are F and one or two of the remainders, equal to or different from each other, are selected from H, Cl, Br, Iodine; when the substituents selected from H, Cl, Br, Iodine are two, they are both linked to the same carbon atom; when R_5 and R_7 , or R_6 and R_8 , are linked each other to form with C^2 and C^1 a $\text{C}_5\text{-C}_6$ cycle fluoroalkyl group, one of the two free substituents R_6, R_8 or R_5, R_7 is F and the other is selected from H, Cl, Br, Iodine.

- the fluoroalkene used in the reaction a) is replaceable with that of the subsequent reaction b); in this case the meanings defined for the substituents of the R_1 - R_4 group, and respectively of the R_5 - R_8 group, are interchangeable each other, with the proviso that the position of each radical of each of the two groups R_1 - R_4 and R_5 - R_8 with respect to $-OCF_2O-$ on the chain of the intermediate compound (VII), is the same which is occupied if the synthesis takes place according to the above reported scheme and the two olefins each react in the considered steps.

13. A process according to claim 12, wherein in step a) the reactants are in an approximately unitary molar ratio, or with an excess of $CF_2(OF)_2$, the residence time of the mixture in the reactor ranges from few hundredths of second up to about 120 seconds, the reaction temperature from -40 to $-150^\circ C$ and the compound (VI) is not separated and is transferred in a continuous way into the reaction of step b).
14. A process according to claims 12 and 13, wherein in the step b) the $R_5R_6C=CR_7R_8$ olefin at a pure state or in solution, reacts with the product obtained in the first reaction with formation of the compound (VII); the olefin is fed in a continuous way, so as to maintain its concentration constant in the reactor; the temperature of the reaction b) can range from -50° to $-130^\circ C$, preferably from -20° to $-100^\circ C$, the olefin concentration is higher than or equal to $0.01M$, preferably the concentration is higher than $3M$, more preferably also the pure compound can be used.
15. A process according to claims 12 and 14, wherein in the step c) the compound (VII), dependently on the olefins used in steps a) and b), after distillation from the reaction raw material, is subjected to dechlorination or to dehydrochlorination to obtain the vinylethers of formula (I).
16. A synthesis process of the (per)fluorovinylethers according to claims 12-15, wherein the compound (VII) is obtainable by reaction of a hypofluorite of formula $X_1X_2C(OF)_2$ wherein X_1 and X_2 equal or different are F , CF_3 , and two fluoroalkenes of formula respectively $RA_1RA_2C=CRA_3RA_4$ and $RA_5RA_6C=CRA_7RA_8$, wherein RA_1 - RA_8 equal or different, are F , H , Cl , Br , I , $-CF_2OSO_2F$, $-SO_2F$, $-COF$, C_1 - C_5 linear or branched perfluoroalkyl or oxyperfluoroalkyl group.

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(54) **Fluorovinylethers and polymers obtainable therefrom**

(57) Fluorovinylethers having the formula $CFX=CXOCF_2OR$, wherein R is a C_2-C_6 linear, branched or C_5-C_6 cyclic (per)fluoroalkyl group, or a C_2-C_6 linear, branched (per)fluoro oxyalkyl group containing from one to three oxygen atoms; when R is fluoroalkyl or fluoroalkoxy group as above defined, it can

contain from 1 to 2 atoms, equal or different, selected from the following: H, Cl, Br, I; X = F, H; and homopolymers or polymers obtainable polymerizing said fluorovinylethers with at least another polymerizable monomer.

EP 1 148 041 A3



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| Place of search MUNICH | | Date of completion of the search 24 November 2003 | Examiner Bueno Torres, M |
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